SECTION 02360

DRIVEN PILES

PART 1 - GENERAL

0.1 DESCRIPTION OF WORK

A. Work Included: This Section specifies furnishing, installing, and testing driven piling for structures. Piling shall be end-bearing or friction piling as indicated.

B. Type of piling, as indicated on the Contract Drawings:

1. Type A: Steel H-piles, driven
2. Type B: Precast concrete piles, driven.
3. Type C: Pretensioned precast concrete piles, driven.
4. Type D: Uniformly tapered or step-tapered thin wall steel shells, closed-end, mandrel driven, concrete filled.
5. Type E: Cylindrical thin wall steel shells, closed-end, mandrel driven, concrete filled.
6. Type F: Steel pipe shells, closed-end, mandrel driven, concrete filled.
7. Type G: Timber piles, peeled and treated, driven.

C. Related Work: The following items are not included in this Section and will be performed under the designated Sections:

1. Section 03300 - CAST-IN-PLACE CONCRETE.

0.2 DEFINITIONS

A. Test Pile: An individual pile, which is observed to determine its behavior during driving and under static axial compression load.

B. Reaction Pile: An individual pile which provides the reaction load required to perform the load test on a test pile. During this process the reaction pile can be subjected to either an axial compression load or an axial tension load.

0.3 SUBMITTALS

A. General: Submit the following for acceptance by the Engineer not less than ten days prior to the start of the respective work:

B. Shop Drawings

1. Type A: Show typical details of size, weight, splices, tip construction and welding design of section connection.
2. Type B: Show typical details of sizes, configuration, reinforcing, class of concrete, lifting devices and curing method.
3. Type C: Show typical details of sizes, configuration, prestressing steel, tendon arrangement, class of concrete, lifting devices, curing methods, and prestressing methods. Include engineering calculations of working stresses.
4. Types D, E, and F: Show typical details of sizes, configuration, tip construction and welding design of section connection, and class of concrete fill.
5. Type G: Show typical details of sizes, tip and butt configuration, and accessories.
6. Piles intended for use as reaction test piles: Show tension steel reinforcing and connections for uplift loads.

C. Pile Driving Sequential Layout

1. Submit layout drawings showing the proposed sequence of driving the piles.
2. On the sequential layout show each pile identification as indicated on the Contract Drawings, its driving sequence number, type, size and load bearing capacity.

D. Pile Driving Record. Maintain a pile driving record during pile driving and submit it to the Engineer upon completion of pile driving. On the record indicate, for each pile driven, the information specified, and the following: type and rating of driving equipment, blow count, number of blows per inch penetration for the last 12 inches, and any unusual conditions encountered during driving.

E. Equipment Review and Working Drawings

1. Submit complete list of the equipment proposed for use, including a description of the characteristics of each piece of driving equipment.
2. Submit working drawings of driving accessories showing compatibility with the size, configuration, handling, and driving requirements of each type of pile indicated on the Contract Drawings.
3. Submit working drawings showing the methods and equipment proposed for loading test piles.

0.4 QUALITY ASSURANCE

A. Installation Tolerances

1. Deviation from plumb and angle of batter: 1/4 inch per foot of pile length.
2. Deviation from location of pile top: three inches.

B. The Engineer will review the proposed driving equipment, accessories, and methods for adequacy for the conditions expected to be encountered. However, the adequacy of the equipment and accessories shall remain the responsibility of the Contractor. Should the equipment used by the Contractor prove inadequate to drive the scheduled types of piles in the locations shown, or should the use rate of accessories show damage to the piles, or should the Progress Schedule not be maintained, the Engineer may require replacement, or different types of expendable accessories, or additional equipment. Comply with such orders at no additional cost to the Authority.

C. Piles delivered to the site shall be visually inspected prior to installation. Piles which are cracked, bowed, chipped, undersize, or which break under driving stresses will be rejected; remove such piles from the site and replace with sound piles at no additional cost to the Authority.

D. Manufacture precast concrete piles to the following dimensional tolerances:

1. Cross section: minus 1/4 inch, plus 1/2 inch.
2. Wall thickness in hollow sections: minus 1/4 inch, plus 3/8 inch.
3. Deviation from straight line: not more than 1/8 inch per ten feet length.
4. Deviation of internal core or void from indicated position: plus or minus 3/8 inch.
5. Deviation of pile head from true right-angle plane: plus or minus 1/4 inch per foot of head dimension.
6. Surface irregularities: plus or minus 1/8 inch.
7. Location of reinforcing steel
    a. Main reinforcement cover: minus 1/8, plus 1/4 inch.
    b. Spacing of spiral reinforcement: plus or minus 1/2 inch.

PART 2 - PRODUCTS

0.1 TYPE A PILES

A. ASTM A36 and the AISC Manual of Steel Construction.

0.2 TYPES B AND C PILES

A. Reinforcement: Section 03300 - CAST-IN-PLACE CONCRETE.

B. Wire: ASTM A416 or ASTM A421, as indicated.

C. Concrete: Comply with Sections 03300 - CAST-IN-PLACE CONCRETE, Class as indicated on the Contract Drawings, or if not indicated, as necessary to meet the bearing capacity shown on the Contract Drawings.

D. Forming Equipment. The placing of concrete, reinforcement and handling accessories; pretensioning equipment and methods; curing procedures; handling and storing methods shall all be subject to review, inspection and acceptance by the Engineer; however, the adequacy thereof shall be the responsibility of the Contractor.

0.3 TYPES D AND E PILES

A. Shells: Alloy conforming to SAE 1006, 1010 or 1015, plain, spiral-corrugated or fluted design.

1. Shells for Type D Piles: tapered or step-tapered. Shells for Type E Piles: cylindrical.
2. Gauge of metal and shell reinforcement of sufficient strength and rigidity to permit installation, and to prevent distortion caused by soil pressures after removal of the mandrel.
3. Tip: ASTM A36 steel plate, thickness as indicated, welded to shell.

B. Concrete Reinforcement: Section 03300 - CAST-IN-PLACE CONCRETE.

C. Concrete: Sections 03300 - CAST-IN-PLACE CONCRETE, Class 4000-3/4 minimum.

0.4 TYPE F PILES

A. Shell: Steel pipe conforming to ASTM A252, Grade 2, Seamless, diameter and weight as indicated.

B. Concrete Reinforcement: Section 03300 - CAST-IN-PLACE CONCRETE.

C. Concrete: Sections 03300 - CAST-IN-PLACE CONCRETE, Class 4000-3/4 minimum.

0.5 TYPE G PILES

A. General: ASTM D25, cut above the ground swell from sound live trees, clean-peeled, pressure-treated as specified below, uniformly tapered from butt to tip, free of short kinks, with a line from center of butt to center of tip lying wholly within the body of the pile.

B. Butt and Tip Dimensions (peeled):

Length	Minimum Dimension 3 ft. from Butt	Minimum Tip Dimension
Up to 40 ft.	12 inches	8 inches

40 to 50 ft.	12 inches	7 inches
50 ft. & over	13 inches	6 inches

1. Maximum dimension three feet from butt: 20 inches.

C. Species:

1. Southern Yellow Pine for piles requiring 16 pcf or more of creosote.
2. Southern Yellow Pine, Douglas Fir (coast region), or Red Oak for other piles.

D. Preservative Treatment

1. Preservative: AASHTO M-133.
2. Method of Treatment: AWPA C1, C2, and C3, full cell or empty cell process for 12 pcf retention, full cell process for retention greater than 12 pcf.
3. Minimum Creosote Retention:

Surrounding Material	Retention, pcf
Earth	12
Fresh Water	16
Salt Water	20

PART 3 - EXECUTION

0.1 GENERAL

A. The Construction Specifications will specify whether piling shall be end-bearing or friction type. End-bearing piles shall be driven to the required bearing value. The bearing value for each pile shall be determined by the applicable formula below. Friction piles shall be driven to the required penetration, as determined by the Engineer, and as specified herein.

B. The Contract Drawings show the required type of piling; the required bearing value; and the estimated pile tip elevation. The estimated tip elevations are approximate, based upon subsurface explorations, and are given only to show the basis for the estimated quantities indicated on the Schedule of Bid Items and to indicate required lengths of test piles. The Contract Drawings also show the required locations of test piles.

C. Based upon the information indicated on the Contract Drawings as described above, the Contractor shall order and drive the test piling. The safe bearing capacities of the test piling will be determined by the Engineer by methods described below. From the test pile data and

behavior and the subsurface exploration data, the Engineer will determine the penetration required. The Engineer may also determine the required penetration based upon settlement criteria or any other factors which in the opinion of the Engineer are applicable to the work.

D. Bearing Value and Penetration: The determination of the safe bearing value will be obtained from observing and recording the behavior of the test pile from the time first placed in the leads until it attains practical refusal or reaches the penetration shown on the Contract Drawings; and by load testing. Safe bearing value on a pile will be computed from the following formula:

$$R = \frac{2\,W\,H}{S + 0.1(P/W)}$$

where:

R = safe load on a single pile, pounds
W = weight of striking parts of hammer, pounds
H = height of fall less twice the height of bounce, feet
S = average penetration for the last 5 to 10 blows for gravity hammers and the last 10 to 20 blows for steam hammers, inches per blow
P = weight of pile as driven, pounds

E. Where test piles are not indicated, the Engineer will determine the required penetration by the above formula. The piles to be driven for this purpose will be shown on the Contract Drawings.

F. Practical Refusal:

1. Practical refusal will be determined by the Engineer, and will be a condition where the blow count exceeds either two times the number of blows required in one foot or three times the number of blows required in three inches to achieve the required bearing value, calculated in accordance with the formula in the paragraph above. Piling reaching practical refusal shall not be driven further.
2. If determined to be necessary by the Engineer, install driven piles meeting practical refusal in accordance with Part 3 “Installation of Piles” Article.

0.2 PILE LOAD TESTS FOR PILES UNDER AXIAL COMPRESSION LOAD

A. Install test piles and reaction piles, of the same type and kind as permanent piles, in the locations indicated on the Contract Drawings or at other locations required by the Engineer.

1. Reinforce reaction piles for the full length to resist uplift loads.
2. Install test piles vertically.

B. Test piles which pass the load test in an undamaged condition may be utilized as permanent piles in the work. Reaction piles which were used to perform the pile load test may be utilized as permanent piles in the work, provided they are not damaged and that they are not moved upward. Either withdraw damaged test piles and reaction piles and remove from the site, or cut them off three feet below any structure to be installed above.

C. Comply with ASTM D1143 for pile load test apparatus, for applying load and measuring movements, and for standard measuring procedures. Loading procedures as follows:

1. Commence loading of test piles not sooner than 72 hours after installation. Apply the load in at least five increments equal to 50, 100, 150, 175, and 200 percent of the design allowable bearing capacity for the individual pile. Maintain each test load, except the maximum test load, for four hours. Maintain the maximum test load for not less than 48 hours. Maintain the 100 and 200 percent test loads on the pile until one of the following conditions exist:
   a. The pile has failed as determined by the Engineer.
   b. The rate of gross settlement over a 24 hour period is less than 0.02 inch per hour.
2. Commence removal of the maximum test load after the test load has been applied as described above. Remove the maximum test load in decrements of 50 percent of the design allowable bearing capacity of the pile, at intervals of four hours.
3. Measure the settlement and rebound of the test pile to the nearest 0.01 inch.

D. Do not subject reaction piles which are to become permanent piles to uplift loads greater than 70 percent of the required bearing capacity.

E. Safe bearing capacity of the test pile shall be one-half of the test load producing a net settlement equal to 0.0025 inch per ton of applied test load. The safe bearing will be obtained graphically by plotting the load versus net settlement for each applied test load cycle. If the net settlement is more than 0.0025 inch per ton for a test load of 200 percent of the required bearing capacity, the Engineer may require additional test piles. When the safe bearing capacity of the pile is less than 90 percent of the required bearing capacity the Engineer will require additional load tests.

F. The Engineer may require the Contractor to make additional load tests not specified in the Construction Specifications or indicated on the Contract Drawings, in the event that the behavior of the test pile or any other pile shows any peculiarity, erratic actions, or otherwise causes suspicion as to the reliability of the safe bearing capacity determined by the formulae given herein.

G. Immediately following completion of load testing, submit two copies of a test report to the Engineer. Include in the test report the data required by ASTM D1143.

H. Following the driving of test piles and the completion of load tests, the Engineer will make a determination of the required penetration as specified herein.

0.3 INSTALLATION OF PILES

A. General. Provide piling of the type indicated and of the length and configuration necessary to:

1. Achieve the required penetration determined by the Engineer;
2. Extend into the pile cap or structure footing to the location indicated on the Contract Drawings; and
3. Attain the indicated bearing capacity.

B. Install piling to the required penetration, or to the required bearing, as indicated, except as specified. Water jetting to obtain the required penetration will not be permitted.

C. Predrilled Holes

1. Where piling is to be driven through embankment and the depth of the embankment is greater than five feet at the pile location, drive piling in a pre-drilled hole, drilled through the embankment, of diameter not less than the greatest cross-section dimension of the piling. After driving the pile, fill any annular space around the pile with dry sand or pea gravel.
2. When pre-drilling is necessary to achieve the required penetration, drill holes of diameter not greater than 90 percent of the least cross-sectional dimension of the piling at the depth being drilled, and drive the pile therein at least five feet or to practical refusal.

D. Drive Piles

1. Complete backfill to the required elevations in the area which piles are to occupy before starting to drive piles.
2. Do not drive piles within 20 feet of concrete less than seven days old.
3. Drive piles at interior of bases of footings before driving perimeter piles.
4. If necessary, provide adequate lateral support for installed individual piles, to prevent excessive temporary flexural stresses or movement of the pile top out of tolerance.
5. Maintain the hammer coaxial with the pile during the driving operation by using a combination of driving cap and leads. Piles shall be driven by approved hammers. Power hammers include single, double, and differential acting air or steam hammers, open and closed-end diesel hammers, and hydraulic hammers. Equipment used to drive production piles shall be identical to the equipment used to drive acceptable test piles.
6. Investigate any sudden decrease in driving resistance for possible breakage of the pile. If sudden decrease in driving resistance cannot

be correlated to boring data or some incident in the driving, and if the pile cannot be removed for inspection, such decrease in driving resistance will be cause for rejection of the pile.

7. Redrive any pile which is raised during driving of adjacent piles, to at least the original tip elevation, at no additional cost to the Authority.
8. Splice piles only by methods and at places accepted by the Engineer.
9. Cut off piles at top elevation indicated on the Contract Drawings. Replace or repair, to the satisfaction of the Engineer, piles which are damaged when cut off, at no additional cost to the Authority.

E. Type A Piles

1. Design the driving cap with grooves in the base that loosely conform to the shape of the pile. The bearing surface of the grooves must be true, without roughness. The driving cap shall extend down the side of the pile at least four inches and be loosely attached to the hammer so that it will at all times rest squarely over the entire surface of the pile.
2. Make splices as detailed on the Contract Drawings by electric-arc field welding in accordance with AWS D1.1. Cut-off damaged portion of pile top before splicing. Take care to align the sections connected so that the axis of the pile will be straight.

F. Types B and C Piles

1. Protect the heads of piles from direct impact of the hammer by accepted cushion head block, so that no cracking, spalling or chipping occurs.
2. Where piles are designed with extended reinforcing steel and protective concrete has been placed for driving, remove such protective concrete to expose the reinforcing steel upon completion of driving, as part of the work of this section.
3. When piles are driven or cut off below the elevation of the bottom of the cap, extend the pile to the elevation of the bottom of the cap by means of a reinforced concrete extension. Submit details to the Engineer for acceptance prior to fabrication.
4. Spudding will be allowed.

G. Types D, E and F Piles

1. Shells will be inspected for collapse, tears, splits or reduced diameter throughout their length after shells have been driven and before reinforcing steel and concrete are placed therein.
2. Provide adequate inspection equipment to the Engineer upon request.
3. For acceptance, the pile shell shall be:
    a. Free of collapsed sections and tears;
    b. Free of water, except that a minor amount of water may be allowed if it can be absorbed by placing a suitable amount of dry sand-cement mixture in the tip of the pile; and
    c. Visible to the bottom of the casing.

4. Remove rejected pile shells and replace with new shells. When rejected shells cannot be removed, furnish and install replacements. Cut off abandoned shells three feet below the structure and fill the abandoned shells with Class 2500 concrete. Backfill and compact holes.
5. Immediately prior to installing the reinforcing steel assembly, place a 1:2 sand-cement grout in bottom of pile shell to a minimum depth of 12 inches.
6. Assemble reinforcing steel as a complete unit and install in pile before starting to place concrete.
7. Place concrete by dumping through a short funnel hopper on the top of the shell. Vibration of the concrete will not be required except in the top 15 feet of the shell. Discharge concrete into the hopper at a continuous and rapid rate.

H. Type G Piles

1. Fit timber piles with metal shoes on the tip as shown on the Contract Drawings. When the area of the head of a timber pile is greater than that of the face of the hammer, use a suitable cap to distribute the blows throughout the cross section of the pile. Do not dress tenons on the heads of timber piles.
2. After timber piles are cut off, treat cut surfaces in accordance with AWPA M4.

I. Remove piles not meeting the requirements specified and replace with acceptable piles, except as herein provided. The Engineer may accept piles which do not meet these tolerances, subject to acceptable redesign of the pile group and pile cap. Provide redesign and revised construction at no additional cost to the Authority, except where the failure to meet tolerances is the result of changed conditions as specified in the General Conditions.

J. Repair or replace piles which are split, broken or otherwise damaged. Perform such repair at the discretion of the Engineer, subject to acceptance upon completion and at no additional cost to the Authority.

PART 4 - MEASUREMENT AND PAYMENT

0.1 MEASUREMENT

A. Piling incorporated in the completed work will be measured by the linear foot complete in place. The length to be measured shall extend from the tip of the pile to the plane of the pile cutoff.

B. Extensions will not be measured separately, but will be included in the measurement of the pile. Splices will not be separately measured for payment.

C. Cutoffs will not be measured for payment, but will become the property of the Contractor.

D. Test piles and reaction piles not incorporated in the completed work will be measured per each.

E. Load testing of piles will be measured per each test performed.

F. Rejected piling will not be measured for payment.

G. Predrilling will not be measured separately, but will be included in the measurement of the pile.

0.2 PAYMENT

A. Piling will be paid for at the Contract unit prices for the quantities determined as specified above.

0.3 PAYMENT ITEMS

ITEM NO.	DESCRIPTION	UNIT
0230.100	PILING	LF
0232.215	DRIVE TEST PILE	EA
0232.228	PILE LOAD TESTS	EA

END OF SECTION

NOTES TO THE DESIGNER

A. Any request to modify or waive the specification requirements listed below must be approved in writing by the MBTA's Director of Design:

1. Wood piles must be certified pressure-treated, unless a specialty untreated pile is specified.